CHAPTER 7

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Bakery Products

INTRODUCTION

The wholesale baking industry is one of the largest users of some form of skim milk or milk solids not fat (msnf). Dried skim milk is the most popular form and is usually written as nonfat dried milk (ndm). Estimates of the total domestic production and baking usage of the dried milks are given in Table 7.1. Over the 4 yr from 1964 to 1967 usage of ndm in baked goods has been somewhat constant, and except for 1965 the usage of dry whole milk was similarly constant. Both the production and bakery usage of buttermilk solids have declined over the same periods.

It is thought that the declining per capita consumption of ndm in the bakery trade is due in part to the advent of continuous bread baking which is estimated to command about 40% of the wholesale bread market. Continuous breads are not very tolerant to levels of ndm exceeding about 1 or 2%. Another factor may be the rapid rise in prices for ndm from about \$0.15 or \$0.16 per lb (1961–1965) to about \$0.22 per lb in 1968.

In addition to the use of milk solids by the baking industry, 69.9 million pounds of ndm and 10.3 million pounds of buttermilk solids were used in prepared mixes in 1967.

Most of the ndm is dried by the spray process. Only about 40 million pounds per year are presently roller dried, although roller-dried ndm is as good or better in functional performance as the spray-dried milks. However, because of their cooked flavor, poor solubility, and nonuniformity of appearance, roller-dried milks are not extensively used.

Increasingly large quantities of sweet whey are being dried and presumably much is being funneled into the bakery trade. It is interesting to note that 155 million pounds were dried in 1950, 277 million pounds in 1960 and 497 million pounds in 1967. The amount of dried wheys used in baking is not available. Dry whey appears to be replacing ndm in cookies because of its superiority with respect to development of color and texture.

Although no current firm data are available on the utilization of condensed milk products in baking, Greiner (1968) reports not much is

TABLE 7.1

PRODUCTION OF DRIED MILK PRODUCTS AND THEIR UTILIZATION IN THE BAKING INDUSTRY (1967)[1]

Milk Product	Domestic Production Million Lb	Bakery Use Million Lb	%
Dried skim milk	958.1	253.9	26.5
Dried whole milk	59.6	5.3	8.8
Dried buttermilk	58.3	24.2	41.6
Dried sweet whey	497.3	not available	—

[1]American Dry Milk Inst. (1968).

utilized because of difficulties of storage necessary for its handling and holding and because of the improved spray products now available. However, a preference is founded on the belief that better flavor, superior mixing properties, and greater smoothness can be obtained with sweetened condensed milks than with other forms of milk solids. Blends of milk and sugar are considered to excel in retaining milk flavor during processing and in transferring this flavor to the bakery product in which the milk is used.

A survey by Cook (1948) showed milk solids of all types are included in bread to (1) improve taste and flavor of the finished product, (2) improve the nutritive value, (3) improve the inside and outside characteristics of the product, (4) improve toasting and keeping qualities, and (5) increase the yield per batch of dough.

MILK BYPRODUCTS USED IN BAKING

The finest flavored bakery goods are made from whole milk products rather than any of the byproducts from milk. This is because milk fat produces a characteristic pleasing flavor not duplicated by other known food constituents. Where economic conditions permit its use, bakery goods of unsurpassed quality can be produced by the use of whole milk or of its concentrates. However, the byproducts of milk are used to manufacture a large part of commercial bakery products. Even though the milk fat is partly or wholly absent from these byproducts they are highly regarded and widely used for their improvement in flavor and physical characteristics.

Composition

The approximate compositions of concentrated forms of whole milk, skim milk, buttermilk and wheys that may be used for baking are shown in Table 7.2. Detailed composition, figures, and discussion of the fresh byproducts are given in Chap. 1.

TABLE 7.2

APPROXIMATE COMPOSITION OF SOME CONCENTRATED MILK PRODUCTS AND BYPRODUCTS USED IN FOOD MANUFACTURE

Product	Sugar		Composition			
	Lactose %	Sucrose %	Protein %	Ash %	Fat %	Water %
Milk						
Plain condensed	14.8	—	9.3	1.9	10.0	70.0
Sweetened condensed	12.2	42.0	7.7	1.6	8.6	27.9
Dried	38.7	—	26.2	6.1	26.5	2.5
Skim Milk						
Plain condensed	16.2	—	11.1	2.5	0.2	70.0
Sweetened condensed	16.2	42.0	11.1	2.5	0.2	28.0
Dried	52.1	—	35.7	8.0	1.0	3.2
Sweet Cream Buttermilk						
Plain condensed	15.0	—	11.2	2.4	1.4	70.0
Sweetened condensed	15.0	42.0	11.2	2.4	1.4	28.0
Dried	47.9	—	36.0	7.8	4.5	3.5
Sweet Cheese Whey						
Plain condensed	51.3	—	10.1	6.0	0.6	32.0
Sweetened condensed	28.7	38.0	5.6	3.4	0.3	24.0
Dried	72.7	—	14.2	8.5	0.6	4.0
Cottage Cheese Whey						
Dried[1]	65.5	—	13.2	8.5	0.5	3.5

[1]Contains 8.0% lactic acid.

Effects of Milk Constituents in Bakery Products

The constituents of milk byproducts in which the baker is chiefly interested are the milk sugar and milk protein. Skim milk and buttermilk do not differ widely in the percentages of these constituents, but whey contains much less protein and more lactose than do skim milks and buttermilks. However, the whey protein, although small in quantity, is as good nutritionally on a weight for weight basis as the casein. For the baker, the important difference between skim milk and sweet cream buttermilk is that buttermilk contains a somewhat different protein fraction together with most of the lecithin of the cream from which the buttermilk is derived.

Casein is considered to be responsible for the high water absorptive properties of milk solids, although heat is required in milk systems to inactivate the dough softening factor in whey proteins that influences binding of water by casein in bread doughs. Larsen *et al.* (1949) indicate heating by itself may have some effect on absorption of water by casein.

Whey proteins if properly heated may perform satisfactorily in bread but in some products such as biscuits and cake doughnuts they tend to restrict volume and increase toughness.

Lactose is generally considered to possess flavor enhancing properties. In addition it is reported to have tenderizing and softening characteristics somewhat similar to sugar. Whey has a tenderizing effect on leavened goods and contains a high percentage of lactose.

Dried Byproducts

The discussion will be confined largely to consideration of ndm but the merits of using byproducts in the dried form apply also to dry buttermilk and to some extent sweet whey.

The specific advantages that make ndm appeal to the bakery industry are: (1) Because of its low moisture and fat levels, it has good keeping quality at room or lower temperature levels. (2) It is convenient to use because of freedom from moisture which permits accurate weighing, controlled acidity, and reduced losses during handling. (3) It is uniform in quality when obtained from a reliable manufacturer. (4) Its use promotes certain economic advantages such as improved water absorption.

Processing Byproducts for Bakery Use

A discussion of the processes used for the manufacture of dried byproducts is presented in Chap. 5. Byproducts to be used for breads are manufactured following the usual procedures except that a special heat treatment of the milk has been found necessary in order to obtain optimum baking results.

EFFECTS OF HEAT TREATMENT ON MILKS FOR BAKING

The discovery that a definite and rather drastic heat treatment of skim milk prior to condensing is necessary for proper bread baking was first published by Greenbank *et al.* (1927). This work was confirmed and industry has adopted the practice of heating fluid milk to high temperatures prior to condensing and drying. A temperature of 185° F for 30 min is generally considered optimum.

Baking Studies

Compared to heated milk, unheated milk produces slackness or extreme extensibility of doughs. The slackness is especially noted on extended mixing and such doughs fail to tighten up on holding. To compensate for this, less water is added to unheated milk doughs. However, these milks generally still give lower volumes than high heated milks.

Swanson *et al.* (1966) believe the effects causing slackness of dough and low bread volume are two independent factors found in unheated milk. Volume effects can be overcome by heating the concentrate to 175° F for 10 min but slackness is still evident. Polyacrylamide gel analysis indicates this volume effect may be due to the inactivation of component-5 which was originally characterized by Jenness (1959). Component-5 is a fraction along with casein which is precipitated by saturated sodium chloride. On the other hand, milks forewarmed above 165° F for 30 min show both changes of component-5 and whey protein. Since both the slackness factor as well as the volume depressant factor were corrected, it is suggested that the slackness factor was corrected by the interaction of κ-casein and β-lactoglobulin which occurs at 165° F or higher.

Earlier work by Gordon *et al.* (1953) showed the heat labile loaf volume depressant factor in milk resided in the classical lactoglobulin of milk serum protein. Since later work reported on component-5 did not indicate whether or not it resided in the "lactoglobulin" fraction, the delineation of these factors is not clear. Of further interest on this subject, studies by Larsen *et al.* (1949) show unheated serum proteins, as well as casein and lactose all depressed loaf volume relevant to a milk-free bread. Heating of serum protein, but not casein or lactose, corrected the volume completely when using adequate bromate in the formula. The depressions caused by lactose were more extensive than those of the casein even though lactose doughs responded to potassium bromate.

Guy and Pallansch (1969) have shown lactose depresses not only the volume of sponge breads but also yeast activity. Since additional sucrose in the formula restricts volume and inhibits yeast due to osmotic effects, the action of lactose is viewed in a similar manner. However, the degree of yeast inhibition is not as great with lactose as sucrose, probably because sucrose is inverted to monosaccharides doubling its potential molar or osmotic concentration while the disaccharide lactose is not hydrolyzed.

Gordon *et al.* (1954) have shown raw supercentrifuged, acid, rennet produced caseins, and wheys all depress loaf volume compared to a milk-free bread.

Sulfhydryl Studies

Much work on the changes due to heat have centered on the sulfhydryl radical of milk. As milk is progressively heated it develops cooked flavor and odor, i.e., sulfides are liberated and they can be quantitatively measured. Townly and Gould (1943) showed the sulfides originated chiefly from the whey proteins. By farinograph and polarographic studies Stamberg and Bailey (1942) showed that raw milk produced curves which could be duplicated by adding an amount of cysteine hydrochloride equivalent to sulfhydryl content of the milk. By suitable heat treatments of the milk both the sulfhydryl content and dough softening factors are greatly diminished. From farinograph studies they determined that the dough softening factor originated chiefly from the whey proteins. It was thus thought that the deleterious effect was associated with the sulfhydryl of serum protein. However, Larson and Jenness (1950) showed unheated β-lactoglobulin, which constitutes most of the protein of serum or whey protein, also contains most of the sulfhydryl of the whey protein and has no significant effect on loaf volume. Thus the effect of serum protein on bread probably does not involve sulfhydryl groups as was formerly thought to be the case.

Various reagents are used for sulfhydryl determinations and different ones give different results in unheated milks. The time and temperature of treatment, level of contaminating copper, and techniques of methodology employed, all affect results. For instance, thiamine disulfide is a weak oxidizing agent which detects very active sulfhydryl groups produced by heating (Jenness 1954A). As milk is heated at progressively higher temperatures up to 85° to 95°C thiamine disulfide titer quickly increases. At this temperature range it may drop to some extent because of susceptibility to air oxidation (Harland *et al.* 1949). On the other hand *o*-iodosobenzoate, a strong oxidizing agent, oxidizes sulfhydryl groups of cysteine and glutathione to disulfide. On heat treatment, sulfhydryl groups of β-lactoglobulin are activated and oxidized by atmospheric oxygen if the heat treatment is conducted in air. The net result is that the sulfhydryl titer decreases as measured by this means.

Figure 7.1 taken from Larson *et al.* (1951) depicts the action of the two described oxidizing agents.

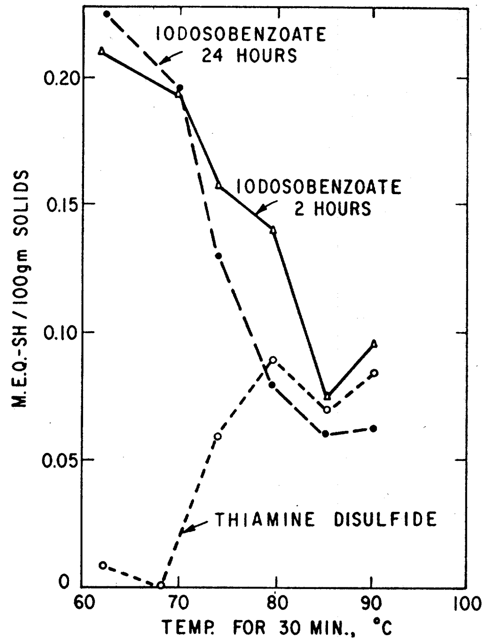
Although the activation of sulfhydryl groups occurs over the same range of conditions required to render serum proteins precipitable, the kinetics of denaturation of these proteins needs much more study to ascertain the extent of parallelism that exists between the various manifestations of these reactions.

SKIM MILKS IN BAKED GOODS

Evaluation of Milks for Baking

The following discussion deals with the evaluation tests for milks and their properties in baked breads, and chemically leavened products. As is customarily done by bakers, addition of ndm to doughs will be expressed as a percentage of the flour weight.

Whey Protein Nitrogen Tests.—To determine the suitability of msnf for bakery use, two tests may be used to determine the amount of undenatured serum protein, reflecting the amount of heat given the fluid milk. (In a milk suitable for bread baking only about 20% or less of serum protein is left undenatured.) In these tests the denatured serum proteins are coprecipitated with casein when the system is either acidified to pH 4.6



Larson et al. (1951)

FIG. 7.1. CHANGES IN SULFHYDRYL ACTIVITY PRODUCED BY HEATING SKIM MILK

or saturated with sodium chloride. Ramsdell and Whittier (1953) showed heat treatment does not precipitate the serum proteins, or cause them to aggregate to very large particles, or to combine with caseinate particles, since the latter can be removed centrifugally from heated milk leaving the serum protein in dispersion. In the Rowland (1937) procedure, casein and heat "denatured" serum protein are precipitated with acetate buffer at pH 4.6 and the noncasein protein-nitrogen of the filtrate is determined by the Kjeldahl procedure. Although this method is accurate, it has the disadvantage of requiring considerable time and equipment.

A faster method was developed by Harland and Ashworth (1947) which depends upon the removal of casein and denatured serum protein by saturation with sodium chloride and subsequent measurement of the turbidity produced by acidification of the diluted filtrate. Modifications have been suggested by Kuramoto *et al.* (1959) and Leighton (1962) to improve the reproducibility and sensitivity of the method. The value of the Harland and Ashworth test lies in the fact that low values—generally less than 1.5 mg undenatured whey protein-nitrogen (WPN)/gm msnf—are associated with good baking quality. Harland and Ashworth (1947) found that of 18 samples of good baking quality ndm, 15 had undenatured WPN values ranging from 0.67 to 1.4 mg/gm. On the other hand, 14 out of 17 samples of poor baking quality ranged from 1.86 to 6.59 mg WPN/gm. Jenness (1954B) has stated the factors limiting the usefulness of the Harland and Ashworth test for assessing baking quality include the variability of milks in total serum protein content and susceptibility to denaturation, and the fact that browning in storage at high moisture levels decreases baking quality without affecting undenatured serum protein content. Doty and McCurrie (1964) claim that in continuous breads WPN remains a quality depressing factor but the effects are not so clearly marked as with conventional batch breads. Baldwin *et al.* (1964) have shown low WPN values are necessary for optimum performance in continuous breads.

Of interest is the fact that Guy *et al.* (1968) showed heating of skim milk containing 0.25% H_2O_2 for 30 min at 63°C prior to concentrating and drying decreased whey protein nitrogen by about 50% to 3.5 mg/gm and slightly raised these values in samples held at 85°C. Both samples yielded higher scoring bread than the control made with high heat treated skim milk. Thus, the use of the Harland and Ashworth test would not be very meaningful as we customarily interpret it for assessing the baking quality of milks processed with H_2O_2.

Farinograph.—Hoffman *et al.* (1948) developed a method to determine the suitability of milks for baking from the farinograph absorption of a 50/50 blend of flour and ndm. Since adequately heated milks absorb more water than low heat milks the test will generally correlate with baking quality. Although developed with roller-dried milks, the test is of value with spray-dried milks. Generally, spray-dried powders of good baking quality show final absorptions of 50% or better and low development times of 10–14 min. On the other hand, low heat ndm shows absorptions of 40% or less and longer development times. Dried milks of intermediate baking quality would have values between 40 and 50% absorption. In these tests the absorption of the flour is taken into consideration in evaluating the absorption of the milk solids. Swanson *et al.* (1964) and Allgauer *et al.* (1954) have shown the flour itself may be a factor in the final absorption of dried milks.

Extensograph.—Although not greatly used because of the time involved and expense of the equipment, Larson *et al.* (1951) report the extensograph characteristics of 12% ndm flour dough correlate well with baking quality. In this test the dough is first mixed to constant consistency thereby eliminating differences due to differences in absorption. The low heat treated ndm showed high extensibility and low resistance to stretching in the machine and in many instances could not be handled by the machine. Swanson and Sanderson (1967) have also shown that a correlation exists for the extensograph values of doughs containing dry milks and final bread quality as evaluated by the continuous method.

Viscosity.—The viscosity of 20%, 30%, and 40% reconstituted ndm are occasionally run as an indication of heat and processing conditions used. The value of the test lies in fact that high heat treatment of fluid milk prior to processing yields dried solids whose viscosity is generally higher than that of low heat powders providing subsequent processing steps are similar. However, Larson *et al.* (1951) report superheated dried milks show higher viscosity values than regular spray-dried milks. Roller-dried powders exhibit the highest values. Since the method of drying and superheating do not bear much relationship to bread baking quality, the test in these instances is of limited value in assessing baking quality. If viscosity is of value in a dry mix or bakery batter containing milk solids, the test can be of some value to control uniformity. The procedures vary but standardization of testing operations is required to obtain uniform results.

Bake Tests.—Since it is impractical to evaluate ndm in a baking test under commercial conditions, a laboratory scale baking test possibly comes closest to approaching this goal. It is best to adopt the formula and as much as possible the method under consideration for the evaluation. However, for breads an experimental method has been proposed for evaluation of ndm by the American Association of Cereal Chemists (1962). This is a pup procedure using a 6% level of ndm with a high-protein hard spring wheat flour. It is considered to be sensitive to baking quality differences of ndm.

Use of Milk in Conventional Sponge Breads

Addition of ndm to the dough in a generally recommended amount of 6% produces certain changes in the physical properties of the dough and in quality characteristics of the resultant bread. These changes have been subjected to extensive studies by baking chemists.

Effects on the Bread Making Process.—The addition of 6% ndm to the remixed sponge and dough raises the pH from about 5.0 to 5.6, the resultant bread being the same or slightly higher in pH. Skovolt and Bailey (1937) showed that in flour suspensions milk suppresses the saccharigenic activity at pH 6.0 but in buffered solutions of pH 4.8 and 4.9 their activity is adequate. Milk thus has the tendency to suppress the action of the diastases at higher pH's. Hence the addition of diastatic malt will generally be advantageous. However, excessive supplementation of milk doughs with diastatic malt may bring about increased activity of proteolytic enzymes and excessive browning of crust, both of which are undesirable. These authors also showed gas production of fermenting doughs is accelerated by ndm if sufficient sugar is available because milk has a stimulating effect on zymase. Thus combinations of malt and sufficient sugar are usually adequate to compensate for this shortcoming of milk.

Effects on Absorption.—Generally for every percentage increase in properly heated ndm water is increased by a like amount. Guy *et al.* (1967A) have shown by the farinograph that when using equal dough masses, the absorption of doughs containing 6% ndm and 2% NaCl are on the average about 5.5 to 6.0% higher than that of doughs containing flour and 2% salt.

If low heat powders are used, to compensate for its softening effect on dough, less water should be used. Although not widely used now, drum-dried skim milk may have the capacity to absorb more water than spray-dried milks. This can be demonstrated by the Hoffman and Dalby test (1948) in which absorptions up to 90% are observed.

When doughs with ndm are mixed the initial uptake of water is slow. Swortfiguer (1963) reports that even fully mixed doughs are slack, but drying will occur past the floor time into the makeup until the dough loses its sheen to make the doughs easy to handle.

Mix Tolerance.—The presence of 6% ndm extends the mix tolerance of doughs. Using straight doughs, Brouilett and McDuffee (1932) showed that the optimum mixing time is the same whether the dough contains milk or not, but longer times may be applied to milk doughs than water doughs without loss of baking quality. Overmixed milk doughs recover much more rapidly and show little evidence of over mixing by the time the dough reaches the pan stage. The crust color of such doughs is normal, and excessive shrinking is not observed upon cooling such bread. The inclusion of milk in doughs is thus of advantage if doughs are inadvertently overmixed.

Fermentation Time.—Because of the stabilizing effect of milk on fermentation reactions, fermentation times of milk doughs are generally longer than milk-free doughs. Laboratory results indicate addition of 6% ndm may not make it necessary to lengthen fermentation times required to produce good bread. However, Brouilett *et al.* (1938) reported commercial tests run in a bakery comparing sponge doughs made with 6% milk solids showed longer fermentation times (floor times) and also better tolerance for milk doughs. Swortfiguer (1963) also reported that floor times of 6% ndm doughs should be double those of milk-free doughs.

The extension of mixing tolerance is also of advantage if unforeseen delays arise in the bake shops to disrupt the schedule. Also, milk, by extending fermentation tolerance, acts to stabilize the dough and therefore moderately contributes toward day to day uniformity of bread.

Bromate Requirements.—Milk solids generally increase the bromate requirements and tolerance of doughs. Table 7.3 taken from data of Harris and Bayfield (1941) shows that the $KBrO_3$ requirements of these flours are increased with the inclusion of 6% ndm. Ofelt and Larmour (1940) found

TABLE 7.3

OPTIMUM $KBrO_3$ REQUIREMENTS WITH 3 FLOURS WHEN BAKED WITH AND WITHOUT 6% NDM[1]

Flour $KBrO_3$	Tenmarq Mgm/100 Gm	Turkey Mgm/100 Gm	Chiefkan Mgm/100 Gm
No milk	2	2	2
With ndm	4	6	4

[1] Harris and Bayfield (1941).

in general the inclusion of 6% ndm greatly increased the tolerance of flour toward bromate and tended to prevent the deleterious effects of excess bromate treatment upon loaf volume and grain and texture. They reported high protein flours require more bromate than low protein flours, and flours which have a slight response to bromate tended to exhibit greater response to milk.

Physical Effects on Bread

Loaf Volume.—The effect of properly heated skim milk on loaf volume is not a uniform response. Some authors report the presence of 6% ndm improves loaf volume and others that it depresses it. Larson *et al.* (1951) reported ndm increased the volumes of breads. However, Guy and Pallansch (1969) find the inclusion of 6% ndm depressed volumes of sponge breads relative to a water control when their doughs were proofed for a constant time. Larson *et al.* (1949) reported ndm depressed volumes relative to a water control. Factors such as bromate levels, fermentation times, malt levels, and formula as well as flour types may affect the baking response of milk and milk-free doughs differently. Thus, it is difficult to generalize in any comparative manner how milk affects volume. Some deviation of volume is not significant; while uniformity of baking response is. Milk exerts a controlling influence on loaf appearance, giving a more even break and shred and smooth sidewall appearance.

Grain and Texture.—It is generally considered that milk solids confer an improved grain and texture score to bread. Harris and Bayfield (1941) and Ofelt and Larmour (1940) reported that the presence of milk improved grain and texture as well as volume probably because grain and texture improvements generally parallel volume increases unless too large. The improvements due to milk may be described as a soft, more velvety texture and a grain of small uniform cells.

Keeping Quality.—The effects of milk on the keeping quality of bread have been the subject of numerous investigations, but definite conclusions have not been reached. Bread staling is commonly thought to be the result of loss of moisture from the loaf, but it has been found that bread stales (becomes firm) rapidly in sealed containers from which no moisture can escape. This is considered to be a transfer of moisture from starches to the proteinaceous bread constituents. Today softening agents are added to bread. They initially soften the bread and although the bread stales, it tends to maintain its soft characteristics for longer periods of time than does untreated bread. In some recent studies, Siebel and Swanson (1968) found milk significantly reduced staling rates in liquid ferment bread but with sponge breads only emulsifier had a significant effect in this regard. It is interesting to note in this regard that 6% ndm gave large loaf volumes in the liquid ferment process which probably contributed to the softer crumb.

Color.—The use of ndm, especially at the 5 to 6% levels imparts a darker brown crust color to breads when incorporated in the formula. It was originally assumed that milk sugar was responsible for the dark color but subsequent investigations, however, showed no single component was responsible for this observation. Color formation during baking is due to a combination of dextrinization, carmelization, and melanoidin formation. Melanoidins, the principal substances of bread crust, are formed by a reaction between reducing sugars and milk amino acids under the influence of heat. Since the lactose of milk is not fermented by yeast, its full reductive capacity is available for reactions with amino acids. Doughs containing high amounts of residual sugar, such as milk or young doughs will therefore color more rapidly than will doughs in which very little residual sugar is present, such as old doughs or milk-free doughs. In high sugar doughs, regardless of the source of sugar, the degree of crust coloration cannot be taken as an indication of the degree of baking. Generally milk doughs must be baked to a deeper color than milk-free doughs to yield well baked bread. The mistake is often made of reducing the sugar in order to get the desired crust color. It is recommended that oven temperatures be slightly reduced and oven times slightly increased.

Other Effects

Nutritive.—From the long range point of view, probably the most significant benefit resulting from the addition of any type of milk solids to bread is the improved nutritional value imparted to bread. This is especially true with people who subsist on a high level of bread in the diet, with deficiencies of vegetables and good quality protein. Fairbanks (1938, 1939) has shown with rats employing bread as the sole source of food, that inclusion of either 6 or 12% milk solids in the bread produced significantly greater gains in weight and rat length.

Water bread is known to be low in proteins, minerals, and vitamins. Wheat flour is considered to be low in the essential amino acids lysine, tryptophan and methionine, and possibly threonine. Mykleby (1960) reports that the inclusion of milk solids at a 6% level will increase the lysine content of bread by 46%, the tryptophan by 10% and the methionine by 23%. Nutritionists have for years contended that calcium and riboflavin are the two nutrients most likely to be deficient in the American diet. Since ndm contains on the average about 20 times the ash content of white flour on an equal weight basis, the use of 6% ndm in breads will increase the calcium by 66%, and riboflavin by 13%. Milk, also being rich in potassium and phosphorus, will significantly increase the content of these minerals.

Flavor and Eating Quality.—A fact of practical interest and advantage to commercial bakers is that the addition of ndm to breads increases its acceptibility. Studies made by Jack and Haynes (1951) shown in Table 7.4 demonstrate the increased acceptance of bread when msnf are added.

TABLE 7.4

INCREASED CONSUMPTION AS RELATED TO MILK LEVEL IN BREAD[1]

Level of Nonfat Dry Milk %	Increased Consumption Over Water Bread %
0	—
6	4.4
10	7.5
14	12.6

[1]Jack and Haynes (1951).

Cost.—Even though actual cost per pound of ndm is presently about three times that of flour, the ndm costs cannot be used as a rule for measuring the amount of milk to add, since the dough yield and baking yield can be calculated to actually affect a slight reduction on the total cost per pound of bread. The greatest saving accompanying the use of skim milk is easily recognized when it is remembered that for each pound of ndm incorporated into the dough a like amount of water is added. As a result the moisture content of the finished loaves with 6% ndm averages about 1% higher than milk-free breads when baked under similar conditions. Thus with ndm, one can get bread at very little to no extra cost with all the quality benefits of its use in bread.

Use of Milk in Continuous Breads

Within the last 10 yr, the advent of continuous bread making process has revolutionized the manufacture of commercial breads in the United States. It is estimated that about 30 to 40% of the commercial bread is made by this process. It is an almost fully automated process in which doughs containing a prefermented liquid or semifluid flour and/or milk sponge are added to the rest of the ingredients, and mixed under high shear rates in a closed mixing head. The dough is then automatically extruded into pans, then proofed, and fully baked. Generally higher absorptions and dough temperatures are used in the process than in conventional sponge breads.

The Problem of Using Milk.—It soon became apparent that normal levels of 3 to 5% of ndm were especially troublesome when using this process for making bread. Volumes were low and, equally important, the bread had poor grain, texture and color. Stronger spring wheat flours might be used to better advantage but these flours are more costly than lower protein flours of choice. Using a commercial size unit, Mauseth *et al.* (1966) showed that as the milk level increased, grain cell structure became progressively more open, optimum mixing speed at constant product rate decreased, and total score decreased. In these studies for each percentage increase of ndm, absorption was increased by a like amount. The results are shown in Table 7.5.

TABLE 7.5

EFFECT OF MILK IN CONTINUOUS BREAD[1]

Milk Solids Level %	Grain Score	Optimum Mixing Speed Rpm	Bread Scores
1	8.9	231	83.1
3	4.4	197	69.7
5	1.1	183	65.3

[1]Mauseth *et al.* (1966).

Progress in Use of Milks in Breads.—Claims that addition of certain ingredients to milk doughs or flour in the brew increase the tolerance of milk in continuous breads have been made. Swortfiguer (1962) reported that careful control of factors including ingredients and processing to arrive at a quality zone permits the use of up to 6% ndm in continuous breads. Trum and Rose (1964) reported that addition of 50% flour in the brew increased the tolerance of bread to milk depending upon the quality of milk as well as the quality of flour.

Vidal and Traubel (1965) reported the addition of azodicarbonamide to flour, when using KIO_3 and $KBrO_3$, significantly increased the specific volume and grain and texture scores of continuous breads made with 3% and 6% ndm over those scores of bread made with ndm at high levels of $KBrO_3$ and KIO_3. Glabe *et al.* (1964) have shown that combinations of hydroxylated lecithin and carrageenan added to brews containing 3% and

6% ndm increased volumes and total scores at reduced KIO_3 and $KBrO_3$ levels. Carrageenan promoted loaf volume, shape, and texture when msnf were present. Hydroxylated lecithin increased both dough stability and loaf volume. Marnett and Tenney (1961) reported calcium stearyl-2 lactylate (Verv) permits higher levels of milk solids in continuous doughs as well as conventional sponge doughs. Geminder *et al.* (1965) have shown the addition of 0.25 to 0.5% Pruv (sodium stearyl fumarate) to brews imparted mixing tolerance and dough improving and stabilizing effects in the presence of variables involving flour quality, flour level in the brew, absorption level, and milk level.

One of the most recent reports by Patel *et al.* (1967) deals with the use of H_2O_2 to treat milk while being processed. It was found that addition of 0.05 or 0.1% H_2O_2 to fluid milk heated to 88° C for 30 min improved grain, texture, and to some extent volumes of continuous breads made with 6% ndm when controlling absorption, oxidation levels, and mixing speed. Using the Brabender Do Corder, Swanson and Sanderson (1967) found that heating of fluid skim milk at 185° F at alkaline pH's with 1 *N* NaOH and then adjusting the pH back to 6.7 with 1 *N* HCl after heating, significantly increased baking quality scores of continuous breads made with 6% msnf. The optimum pH of skim milk was 8.7. The data showing this is presented in Table 7.6.

TABLE 7.6

EFFECT OF HEATING AT 185°F FOR 30 MIN AT ADJUSTED pH VALUES ON BAKING PROPERTIES OF 6% NDM[1]

pH Heating	Adjusted Loaf Volume Cc/16 Oz	Bread Score
No milk	2570	93
6.2	2123	89
6.7	2000	88
7.2	2114	89
7.7	2173	91
8.2	2313	91.5
8.7	2483	92
9.2	2282	90

[1]Swanson and Sanderson (1967).

It is generally considered that although additions and careful attention to flour usage and processing help, the use of high levels of msnf in continuous breads is still a problem.

Use of Milk in Specialty Breads

Rye.—The inclusion of skim milk in a wide variety of rye bread formulas offers the same advantage as in white bread formulas. Since rye doughs do not tolerate much water and mixing is critical, it is recommended that only about half as much water be added to the ndm as is usually added for ndm used in white bread. With certain flour types sensitive to mixing, all or a major part of the msnf should be added to the sponge with the diastase. Skim milk retards the development of actual acidity but not the titratable or potential acidity which is increased. The inclusion of msnf permits increased fermentation which is more effective in producing flavor constituents than is the reduced actual acidity in permitting their development. The grain, texture, color, flavor, slicing properties and symmetry of rye bread are all improved by skim milk to a point which more than justifies its inclusion in the formula.

Use of Milks in Sweet Goods

Sweet goods in the baking industry is a term used to include a variety of products with the general requirement that the sugar content be 16% or higher. These products may be subdivided into classifications of yeast-raised and chemically-raised sweet goods; the former is illustrated by various forms of "roll in" sweet dough, or plain sweet dough, and the latter by cakes and cookies. Since differences in formula are sometimes considerable, it is difficult to state precisely the exact content of milk solids in various types of sweet goods. However, within reasonable limits the following may be considered typical; figures represent parts of skim milk solids for 100 parts of flour used in the formula:

Yellow layer cake White layer cake	10–12	Pound cake	5–10
Devils food cake Chocolate cake	5–8	Plain sweet rolls Danish rolls	2–6
		Doughnuts	5–6
		Cookies	3–10

The preheat treatment given fluid milk before drying for cakes has not received much attention in the literature. Different commercial users prefer products which have received the opposite extremes of heat treatment. Likewise little is in the literature concerning the effects of heat on milks for doughnuts, although there is a tendency to select milks of high absorptive qualities in these products since fat absorption of the doughnut can be controlled by the water absorption of the batter.

The addition of milk to cakes promotes the following results. (1) Moisture content of the cakes is retained for longer periods of time. (2) Appearance of the interior and exterior of cake is improved; a golden-brown crust is produced with complete absence of oiliness and greasiness. (3) Flavor, richness and taste appeal are improved. (4) Nutritional value of the cake is improved.

BUTTER IN BAKED GOODS

Butter is the best of all shortenings from a flavor standpoint. In the past bakers have preferred low score butter because of price and because of the belief that stronger flavors associated with poorer grades were preferred. However, today, most bakers who stress the use of butter in their products use only the highest grades.

When butter is used it is well to recall that it contains about 16% moisture. Most butter is salted but some is unsalted. On the average salted butter contains about 2.3% salt. Although butter is relatively constant in its composition of fat and moisture, it is subject to considerable variations with respect to consistency, color, and flavor depending upon seasonal variations in feed and upon breed of cows. The method of manufacture also determines to a marked degree the general characteristics of the product, i.e., whether made from sweet or ripened cream or whether salted or unsalted. Butter is extremely sensitive to flavor taints and will absorb easily most odors to which it is exposed for even short periods.

The creaming quality of butter is rather poor. Cakes made with butter are generally lower in volume and have a coarser grain than those made from a high quality shortening with good creaming quality. However, the addition of emulsifiers to butter holds promise for making better cakes. Snow *et al.* (1967) have shown that addition of emulsifiers to butter powders prepared from sugar and milk proteins under definitive conditions of emulsion preparation and spray drying, produced excellent cakes of high volume when chlorinated cake flours were used. In their judgment, butter powder could gain acceptance in commercial baking and cake premix fields where there is control in flour selection and processing.

WHEY PRODUCTS IN BAKED GOODS

Sweet Cheddar and Swiss wheys are finding increased use in baked products because of their flavor enhancing and tenderizing qualities and because of improved low cost drying techniques. Acid cottage cheese wheys now can be dried successfully by the foam spray method but they are not yet extensively used. The cost of dried whey is less than ½ that of ndm and the product appears to have many potential applications. The undesirable factors in milk that may be responsible for poor baking quality seem to be centered in the whey fraction but efforts have been made to produce wheys suitable for bread and other bakery usage. Present indications are that dried whey is replacing from 20–30% of the ndm formerly used in food manufacture. Although whey contains less protein than skim milk its protein is of comparable biological value. Inclusion of whey at the 6% level has been found to increase the nutritive value of bread.

Properties of Dried Wheys in Bread

When replacing ndm with dried sweet cheese whey, absorption should be cut 2 to 3% for a 4% whey bread. Good whey bread can be produced but generally loaf volume is somewhat reduced compared to milk bread. Mixing times with whey may be somewhat extended and machinability of the dough is not as good as with ndm. The fluid whey should be subjected to a high heat pretreatment prior to drying just as is done with skim milk to condition it for bread baking.

Modified Wheys

Because of the limitations of wheys in bread baking, attempts to use them have centered on replacing part of the ndm with dried wheys and also chemically modifying them for specific uses.

Use in Sponge Breads.—When using ndm, up to 2% sweet whey solids may be substituted for 2% ndm in the formula. Thus, when using 3% ndm, use 2% dry whey and 1% ndm, and if using 6% ndm, use 2% dry whey and 4% ndm. In this manner, absorption will have to be dropped only about 1–2% at most to compensate for whey. Guy *et al.* (1967B) found that when replacing ⅓ of 6% milk solids with cottage cheese whey in sponge breads made with either hard red spring wheat or hard red winter wheat flours, grain scores and keeping quality scores were increased. Taste acceptability scores remained unchanged. Cottage cheese whey also permitted greater tolerance to absorption variation. At intermediate and long mixing times, volumes and total scores were maintained with hard red winter wheat flours, and total scores were maintained with hard red spring wheat flours. Ward *et al.* (1962) modified whey by addition of low levels of caseinate protein, and calcium and phosphate salts. Their product is claimed to have absorption and bread baking properties approaching that of ndm when used at a 4% level.

Henika and Rodgers (1965) reported that a blend of 4% dried whey, 80 ppm cysteine and 60 ppm $KBrO_3$ can be utilized in no-time ferment straight doughs to produce good bread comparable to sponge bread. When using this material, the dough is mixed, given 40 min floor time, rounded, relaxed 10 min, moulded, proofed to height, and then baked. Both cysteine and $KBrO_3$ in optimum amounts are required for the production of suitable bread.

Use in Continuous Breads.—Henika *et al.* (1966) have also successfully used a blend of 75 ppm cysteine and 3% dried whey in continuous breads when controlling oxidation and acidity. This process can be successfully carried out with 10% flour brews using reduced brew times, and lower developer speeds at low dough temperatures of 85–88°F to maintain proper absorption. Bread and buns excellent in all respects can be obtained with improved crumb softness.

Use in Cakes.—Addition of whey to cakes brings about increased tenderness—sometimes developing fragility to the cake. In general, cutting back on shortening and sugar of the regular formula containing msnf, for which whey is substituted, tends to compensate for this. Whey may be combined with skim milk or buttermilk and yield cakes of improved grain and texture.

Hanning and De Goumois (1952) reported that the addition of whey to cakes increased volume, tenderness, flavor, browning, and keeping qualities relative to cakes with no milk solids and increased moisture and flavor relative to msnf. Best (1967) reported that compared to 12.5% ndm, cakes made with 10% sweet whey solids and 2.5% ndm at reduced shortening levels give better volume, equal flavor, and are more tender and yet are stabile to handling without being tough.

Singleton *et al.* (1965) recommended the use of cottage cheese whey solids in chocolate cakes as a means of accentuating spices and flavor and Guy *et al.* (1966) reported it has tenderizing and color improving effects on chocolate cakes.

Use in Other Baker Items.—Hofstrand *et al.* (1965) and Potter and Zaehringer (1965) showed in studies with doughnuts and baking powder biscuits that dried whole whey gave results comparable to buttermilk solids. However, the whey proteins by themselves and lactose exerted opposing functional effects. Whey proteins had a toughening and quality depressing effect but the lactose component had a tenderizing and volume maintaining effect. Lactose also enhanced the flavor of biscuits.

Singleton *et al.* (1965) reported whey solids are finding increased use in many bakery applications. Sweet whey is excellent in piecrust dough, giving improved tenderness and flakiness. Shortening and water levels may be kept to a minimum because of tenderizing and low water requirements of whey. Cookies made with whey have excellent flavor and color.

Because of their taste enhancing qualities, sweet whey solids have also been recommended for pancakes, frozen meat pies, casseroles, and pie fillings.

BUTTERMILK IN BAKED GOODS

Because of the lecithin and unique protein fractions in buttermilk, this byproduct has desirable baking properties, particularly in the dried form. Sizable amounts of buttermilk solids are presently used by the mix industry, and one can find in the supermarkets pancake mixes, cake mixes and other mixes containing these solids.

Buttermilk in Bread

Reger *et al.* (1949) found that the 6% level of dry sweet cream buttermilk solids produced bread of improved volume compared to ndm at the same level. It is believed the lecithin content of the buttermilk solids is responsible for the increased loaf volume, since the addition to skim milk before drying of a small amount of soybean lecithin emulsified in butter oil produced a product yielding the same loaf volume as dried buttermilk. The addition of butter oil alone to skim milk did not effect the same results. In the manufacture of canned bread it is desirable to maintain a comparatively high acidity, and, when cultured buttermilk solids are used in the formula in place of skim milk solids, a somewhat lower pH of the crumb can be obtained.

Johnson (1936) has indicated definite advantages to using buttermilk in rye bread both on an experimental and commercial scale. Buttermilk as a flavoring agent in rye bread has been used for many years, but the variation in acidity of the buttermilk often caused undesirable variations in the rye dough acidity and has somewhat limited the use of this milk byproduct. Controlled manufacturing techniques can easily promote a uniform product for baking purposes. Dried buttermilk of 11% acidity has been used to prepare a mixture of buttermilk solids and medium rye flour in a proportion of 15 to 85. This is said to ensure a uniform acidity in the rye bread dough. Buttermilk is responsible for marked improvements in flavor, crust color, crumb texture and structure, and keeping quality in rye bread. Less crumbling during slicing, increased water absorption, and improved nutritive properties and toasting quality are additional advantages.

FUTURE OF MILK USAGE

It is anticipated that milk or milk byproducts will always be used in baked goods because of their functional importance and nutritional value. Milk and milk products have a special appeal because people believe they are associated with the good foods of life along with meat, eggs, and sweets. The thinking is that one can always make superior baked goods with sufficient milk, butter, eggs, and liberal quantities of sugars, syrups, or honeys. However, from the standpoint of bakery processors who are interested in lowering the cost of milk ingredients and being able to sell milk products of good functional quality in baked goods, a wider utilization of milk byproducts will be made. There is much interest in whey utilization, and more markets will be found by blending dry wheys with ndm or fortifying them with caseinates and whey proteins from low cost foreign sources or from surplus domestic milk and whey. The utilization of low cost plant proteins with whey should not be ruled out.

The intensification of butter flavors by heat processing milk fat into ghee, and improving the functional characteristics of butter by the addition of suitable emulsifiers to make it more functional in baked goods opens up the possibilities of further bakery use of butterfat.

FORMULAS AND PROCEDURES

Suggestions for typical formulas of bakery goods containing milk byproducts and for precise schedules of their production can be made only with the understanding that some variation will be necessary in order to meet local requirements. In commercial bakeries it is usually necessary to make several trial runs with the supplies and equipment on hand, and to make adjustments for the use of operation and quality of product on the basis of the results obtained. The following formulas are intended to illustrate some uses of milk byproducts in baking. They should be modified to suit individual needs.

The milk byproduct specified in the formulas is "dry skim milk" or ndm. Frequently it will be desirable to reconstitute the dry skim milk with some of the water in the formula before the ingredients are mixed. This is especially recommended with cakes.

Various combinations of whey, buttermilk, and skim milk solids may be substituted in the formulas for the dry skim milk figure. If skim milk is fully replaced by whey there may be some lowering in quality of the finished product and some adjustments may have to be made. A partial replacement of skim milk by whey will tend to give goods a softer texture and to retard the firming or drying effects of aging. A replacement of dry skim milk by whole milk products will result in a product of marked superiority of flavor and texture.

Sponge Breads

For large commercial bread production, a sponge-dough procedure is chiefly used because of the superior grain, texture, and eating quality. This method can be used in the laboratory shop and for this a water jacketed mixing bowl and humidity and temperature controlled fermentation cabinets are recommended. For mixing the sponge the following ingredients only are scaled into the mixer:

WHITE PAN BREAD (SPONGE PROCESS)

	%
Flour	60–70 (of total amount)
Compressed yeast	2–2.5
Yeast food-bromate type	¼–½
Malt	0–0.5 (depending on flour)
Water	58–64 (variable)

After mixing 1–3 min, the temperature of the dough out of the mixer should be 76°–78°F. The resulting dough is called a "sponge." It is then placed in open fermentation containers and held 3–4 hr at about 85°F and

80% RH. During this time the sponge will increase to a maximum volume and then recede or "fall." The sponge is ready after an additional 25 to 30% longer time for mixing with the remaining ingredients.

For mixing the final dough, the sponge is first transferred back into the mixer and the following ingredients added:

	%
Flour	30–40 (depending on % flour in sponge)
Sugar	6–8
Salt	1.75–2.25
Shortening	3–4
Dry skim milk	0–6
Water	58–64 (variable)

A variable mixing period of several minutes is necessary to produce a dough of optimum handling qualities. The temperature of the finished dough out of the mixer should be about 80° F. The dough is then given a floor time of 20-40 min, after which follows dividing, rounding, a short intermediate proof, panning, proofing at 80–90% RH and 95° to 100° F, and then baking.

Continuous Breads

In the manufacture of continuous breads, rather extensive specialized equipment is required, necessitating a heavy outlay in capital expenditure. However, because of decreased labor requirements and increased productivity, the costs become absorbed with time.

No definite formulas will be given for production of continuous bread because formulations vary from plant to plant. Also as previously mentioned only 1–3% levels of ndm are generally used. In the procedure a liquid brew containing water, variable levels of flour up to 50%, ndm, yeast, yeast food, salt, sugar, calcium acid phosphate, and calcium propionate are allowed to ferment 2–3 hr. Then the fermented brew is added to the remaining flour, spike sugar, and high melting shortening specially designed for continuous bread making along with a mixture of up to 75 ppm total $KBrO_3$ and KIO_3 in a ratio of about 3–4 to 1. The mixture is then optimally developed under high shear in a special mixer head and is automatically panned, leaving the head at about 103° F. The dough is proofed to height at about 100°–103° F. It is then baked at somewhat higher temperatures and shorter times than conventional sponge breads.

A Brabender Do Corder that can be used with 600-gm quantities of flour is available for laboratory evaluations of continuously baked bread. When using this instrument the dough is manually taken from the head, and gently handled for placing in the pans. It can be used to advantage in the laboratory, and reproduces in a satisfactory manner. The manufacturer can supply formulations for use with this equipment.

Cakes and Pastry

In preparation of cakes, local differences are even greater than in the case of bread production. Consumer preference, economic considerations, local conditions and equipment, and formula variations all enter into the picture and no one formula or procedure can be described to cover all objectives.

Three separate types of cake usually recognized by the industry include the foam-type cake (angel food and sponge cake varieties), the white or yellow layer type cake (also loaf cakes and cupcakes), and pound cakes (wine cakes and other varieties produced without chemical leavening agents). Many variations of each type are possible by the use of different proportions of ingredients, flavoring materials, fruits, nuts, etc. The use of shortening containing "emulsifying agents" rather than older types of commercial shortenings, permits a higher proportion of water and sugar, with respect to the same amount of flour, to be incorporated in the cake formula, thus producing the so-called "high-ratio" type cake. Before the improved shortenings were available it was difficult to produce a cake containing more sugar than flour, but cake formulas containing as much as 140% sugar, based on flour weight, are now possible, and this type seems to be preferred by the consumer because of the increased tenderness and improved eating qualities of the finished cake.

Yellow Layer Cake.—The following yellow layer cake is the high-ratio type and is rich; the mixing procedure produces excellent texture and eating qualities in the finished cake, although a somewhat larger volume may be possible with other mixing techniques. A single-stage mixing, in which all ingredients are introduced into the mixer at one time, has been used to advantage, but the finished cake rarely has the improved texture of other mixing procedures. The quality of ingredients greatly affects the cake, and for best results only the highest grade materials should be used. All ingredients should be at room temperature while the temperature of the liquid ingredient should be such that the final cake batter has a temperature of 70° to 75° F.

Yellow Layer Cake

	Parts	
Cake flour	100	Cream together at low speed, scraping down sides of mixer.
Shortening (emulsifier type)	60	
Sugar (finely granulated)	115	Sift together and add to mixer with enough liquid milk to form a stiff paste; mix 3 to 5 min at low speed, scraping down sides of mixer.
Salt	2	
Baking powder	6	
Dry skim milk	10	
Water	65	
Whole eggs	60	Add remainder of milk and eggs slowly; mix 3 to 5 min low speed.

Egg whites may be used in place of whole eggs for white layers.
Batter is scaled into lightly greased pans and baked 25 to 28 min at 365° F.

The final batter should have smooth consistency, flow freely, and be at a temperature of 70° to 75° F. Nine to eleven ounces is generally satisfactory for 7-in. diam pans. Oven temperature should be between 360° to 385° F with care being taken to insure a uniform constant heat. "Flash" heat must be avoided to prevent cakes from too rapid crust formation while the interior of the cake remains unbaked. Finely granulated sugar is preferred in cake work since it dissolves rapidly, giving a smooth batter. Coarse sugar dissolves more slowly resulting in a granular batter, and cakes of coarse grained texture. The undesirable curdling of cake batter, which may occur, is usually the result of improper temperature of ingredients. The slow addition of liquid ingredients and eggs also helps to prevent breaking of the cake batter emulsion.

Cheese Cake.—Cheese cake offers one of the best opportunities for providing the consumer with variety in bakery products. With increasing popularity it promises to become a substantial outlet for soft curd cheeses such as cottage, pot and bakers' cheese. The following formula may be considered a single type of which there are many varieties:

	Parts	
Bakers' cheese	600	Mix smooth for about 3 min.
Bread flour	100	
Salt	5	
Vanilla	5	
Shortening	100	Add and mix smooth.
Sugar	25	
Whole eggs	200	Add in three parts and mix smooth.
Milk (fluid basis)	325	Add slowly.

Egg whites	350	While beating egg whites add sugar slowly; beat to soft peak and then fold into the above mixture.
Sugar	75	

Baking temperature: 300° F
Baking time: 75 min

There is a wide variety of types, formulas and procedures for cheese cake, all requiring considerable practice with some variation to meet shop conditions. The formula and procedure given above are less complicated than many others and produce the standard type cheese cake. Slow baking is necessary to prevent excessive recession of the baked cake. It will rise to high volume during baking, but the recession will not be too great if oven temperature is kept around 300° F. Careful mixing is required at each stage to produce a smooth, uniform batter which will bake into a cake of proper texture and eating quality.

Piecrust.—Piecrust formulas are fairly uniform with the exception of the shortening content. The following formula may be considered representative.

	Parts
Pastry flour	100
Shortening	40–70 (average 55)
Salt	3
Water	30–35
Dry skim milk	2–4
Sugar	2–4
Baking powder	0.12–0.25

Special piecrust flours which are intermediate in strength between bread flour and cake flour are commercially available. A mixture of bread and cake flour is preferred if pastry flour is not available. The amount of shortening as well as flour type determines flakiness and tenderness of crust (amount of water is also important in this respect), although difficulty in handling usually limits the quantities used. In producing a high quality piecrust dough, overmixing should be avoided. Flour and shortening are "cut" either by hand or with special mixing blades until the mixture is in about ¼-in. cubes. Water containing salt, sugar, milk, etc., is added slowly and mixing is continued only until the mass holds together. To avoid excess pan shrinkage and to facilitate handling, pie dough should be 6 or 8 hr old before rolling and baking.

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